TOECAP MADE FROM WOVEN LAYERS OF CONTINUOUS STRANDS ALIGNED IN LAYER-SPECIFIC ORIENTATION

This Application is a Formal Application of a prior Provisional Patent Application 60/438,557 and claims a Priority Filing Date of January 7, 2003.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the toecap for footwear and particularly with the improvement of structural properties thus improving the strength consistence of toecaps.

2. BACKGROUND

Metal toecaps, e.g., steel toecaps, for safety shoes have been in use for many years with strict test rules established by the American National Standards Institute (ANSI). However plastic ones, such as thermoplastic injection molded, have also been made for various reasons including much improved electrical insulation.

Plastic materials have been widely used since World War II. Generally the classification has been divided into thermoplastics and thermosets. The popular definition for thermoplastic is that its material shape can be formed and reformed by the application of heat and pressure. As to thermoset material, its shape or form cannot be reformed as a result of chemical reaction called crosslinking, after the initial heat and pressure. Composites materials are either thermoplastic or thermoset polymeric material that is added with other type of fillers, additives or reinforcements to try to improve certain properties. They have been in use for many household applications ranging from marine yachts, to tennis rackets, fishing rods and golf shafts, or even space shuttle booster tank.

Prepreg materials are fiber tow or fabric that are pre-impregnated with resin system for faster cure time, because fibers are pre-wetted and reduce the resin flow time to wet out the reinforcing fibers and also reduce air bubble entrapped in the parts which could cause structural defects. There are thermoplastic prepreg, but their costs have been relatively high. Thermoset SMCs have been widely used in automotive market. But most resin systems have been unsaturated polyester resin and the unsaturated polyester resin is generally too brittle and unable to sustain the impacts as that required in toecap for safety shoe applications.

Because of molding process, the inventions claimed on toe caps so far have been mostly in thermoplastic fields. Because short chopped strand glass fibers or other type of reinforcements are used, the mechanical properties of these toecaps can be improved by increasing the fiber length. US Patent No. 6,159,589 is one of the examples. The patent claims the usage of interwoven fiber orientation in an injection molded thermoplastic matrix. The needed impact and compression properties can be greatly improved with the introduction of continuous tows.

There are some thermoset applications including claims using thermoset prepreg (pre-impregnated) vinyl ester sheet molding compound reinforced with glass and/or carbon fiber. However sheet-molding compound (SMC) still uses fibers of random orientation or short fibers, so its mechanical properties like impact or compression properties and strength uniformity and stability still have room for improvements.

Therefore, a need still exists in the industry for design and manufacturing toecap of a safety shoes to provide a new and improved materials to overcome the difficulties and limitations discussed above.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide the toecaps for reinforcement of safety shoes or boots and replacement of metal caps. It is

to provide toecaps with increased mechanical strength including tensile, compression and impact properties.

It is another object of the present invention to provide toecaps for safety shoes using fibers with controlled and fixed orientation such that the mechanical strength and also the strength uniformity and directional stability are significantly increased such that the mechanical strength is improved over that can be achieved by the conventional toecaps manufactured by thermal plastic injection molding or the Thermoset SMCs.

It is another object of the present invention to provide toecaps for safety shoes using long fibers with controlled and fixed orientation such that safety shoes of less weight can be provided because toecaps with thinner protective layers are necessary when these layers have improved mechanical strength.

It is another object of the present invention to provide toecaps for safety shoes using long fibers with controlled and fixed orientation such that safety shoes of smooth surface with improved manufacturability and appearance can be provided because toecaps with less content of fiber glass can be used thus improving the smoothness of the surface.

Briefly, in a preferred embodiment, the present invention discloses a toecap comprises woven layers each composed of continuous strands of prepreg material aligned in a layer-specific orientation. In a preferred embodiment, the layer specific orientation of a first of said layer is orthogonal to an orientation of a second layer. In another preferred embodiment, the toecap comprises woven roving layers of continuous strands of prepreg material wherein two adjacent layers have two different layer-specific orientations orthogonal to each other. In another preferred embodiment, the layer specific orientation of a first layer is oriented at forty-five degrees from an orientation of a second layer. In another preferred embodiment, the woven layers further comprise a hybrid layer having a sheet-molding compound (SMC) layer.

A method for manufacturing a toecap is disclosed in this invention. The method includes a step of laying up a plurality of layers wherein each layer composed of continuous strands of prepreg material aligned in a layer-specific orientation.

These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiment, which is illustrated in the various drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A to 1H are perspective views to show layer structure and aligned orientation of continuous strands in each layer of the prepreg materials for making to toecaps;

Fig.2 is a perspective view for showing a SMC molding compound sheet;

Figs.3A to 3J shows a series of processing steps for making toecaps of this invention;

Fig. 3K shows a perspective view of a toecap processed through steps shown in Figs. 3A to 3J; and

Figs. 4A and 4B is a functional diagram for showing a machine and processes for making the pre-preg material of continuous strands and the SMC as part of the hybrid layer structure of Fig. 1C.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figs. 1A to 1H are perspective views for showing that structure and composition of improved structure of materials employed for making toecaps for safety shoes of this invention. As shown in the drawings, the

sheets comprise a prepreg material containing directional continuous reinforcing roving. The preppreg materials may be glass fiber or other type of fibers, such as glass fiber woven roving (made out of roving tow), woven cloth (made out of yarns) or stitchbonded biaxial, trixial and quadraxial fabrics. In contrast to the conventional composite materials such as sheet molding compound (SMC) that uses fibers of random orientations, the continuous strands are aligned in a fixed orientations in each layer. Different layers comprising sheets woven with continuous strands along different orientations are then stacked together. In order to increase the thickness of molded parts to obtain its needed properties, chopped strand mat or stichbonded or nonwoven mat could be used to increase the interlayer bonding strength or on surface to improve surface evenness. For practical consideration, even a toecap of less thickness can be provided to achieve better protective strength than the conventional toecap, however, additional costs will incur due to a new tooling required to make toecap of less thickness. In order to achieve cost savings, this invention discloses a hybrid layer structure with hybrid interlayer using a chopped-strands SMC layer to reduce the material cost. This hybrid layer structure has a same thickness as a conventional toecap that can be conveniently processed by an existing machine to reduce the manufacture cost. A non-woven mat is used as a surface layer to improve the surface smoothness. Fig. 2 shows a nonwoven mat as sheet molding compound.

Figs. 3A to 3J shows the processing steps for making the toecaps of this invention. The prepreg material IQC are die-cut (Figs 3A to 3C) into small pieces. These small pieces are hand lay-up with various plies to form the perform (Figs. 3D to 3G). The orientation of various lay-up plies of fibers is matched depending on mold shape and needed properties. The prepreg layers comprise the continuous fiber strands of fixed orientation have controlled viscosity. In the processes of manufacturing the sheets as that shown in Figs. 1A to 1E, layer-by layer lay-up is carried out by arranging the continuous fiber strands along certain predefined orientation. Because of the controlled viscosity of each layer, there is no relative movement between the layers. Only the resins can flow between the layers. The wall thickness of finished toecaps is from 0.10 to 0.25

inches to comply with a standard requirement of ANSI Grade –1(102 J) or CSA Grade-1 (125J). After the lay-up process, the preforms are then put into and pressed in a mold (Figs. 3H to 3I) and ready for heating and curing (Fig. 3J). When the whole sheet is cured by a heating process, the resin flows between the layers squeezes out the air between the layers thus forming stable high quality sheets of uniform thickness with well controlled mechanical properties. Fig. 3K is a perspective view of the toecap manufactured through the processes shown in Figs. 3A to 3J.

The resin system used can be vinyl ester, unsaturated polyester, epoxy or polyurethance with resin content from 30-60% of weight. There are broad selections of the reinforcement fibers. The reinforced fibers may be glass fibers, carbon fibers, aramid fibers and metal fibers. For the purpose of making the toecaps, an alternate preferred embodiment may be implemented that uses a hybrid material of woven roving/cloth/SMC and vinylestec. An example is shown in Fig. 1C. As shown in the Fig. 1C, a SMC layer is sandwiched between two woven roving layers. Figs. 4A and 4B show a prepreg machine for making continuous strands employed in Fig. 1A to 1H and an SMC-R machine for manufacturing an interlayer SMC layer of Fig. 1C and Fig. 2.

According to above descriptions of different preferred embodiment and the drawings, this invention discloses a toecap that includes woven layers each composed of continuous strands of prepreg material. In a preferred embodiment, the continuous strands of prepreg material for each of the woven layers are aligned in a layer-specific orientation. In another preferred embodiment, the layer specific orientation of a first of the layer is orthogonal to an orientation of a second layer. In another preferred embodiment, the layer specific orientation of a first layer is oriented at forty-five degrees from an orientation of a second layer. In another preferred embodiment, the woven layers further comprise a hybrid layer having a sheet-molding compound (SMC) layer. In another preferred embodiment, the toecap further includes a resin between the woven layers. In another preferred embodiment, the toecap further includes a resin comprising vinyl ester between the woven layers. In

another preferred embodiment, the toecap further includes a resin comprising polyester between the woven layers. In another preferred embodiment, the toecap further includes a resin comprising epoxy between the woven layers. In another preferred embodiment, the toecap further includes a resin comprising polyurethance between the woven layers. In another preferred embodiment, the continuous strands of prepreg material for each of the woven layers comprising directional continuous reinforcing roving. In another preferred embodiment, the continuous strands of prepreg material comprising directional continuous glass fiber. In another preferred embodiment, the continuous strands of prepreg material comprising directional continuous woven cloth made out of yarns.

This invention also discloses a method for manufacturing a toecap that includes a step of laying up a plurality of layers wherein each layer composed of continuous strands of prepreg material. In another preferred embodiment, the step of laying up the plurality of layers further comprising a step of laying up the plurality of layers by aligning each of the of continuous strands of prepreg material in a layer-specific orientation.

Although the present invention has been described in terms of the presently preferred embodiment, it is to be understood that such disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art after reading the above disclosure. Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the true spirit and scope of the invention.